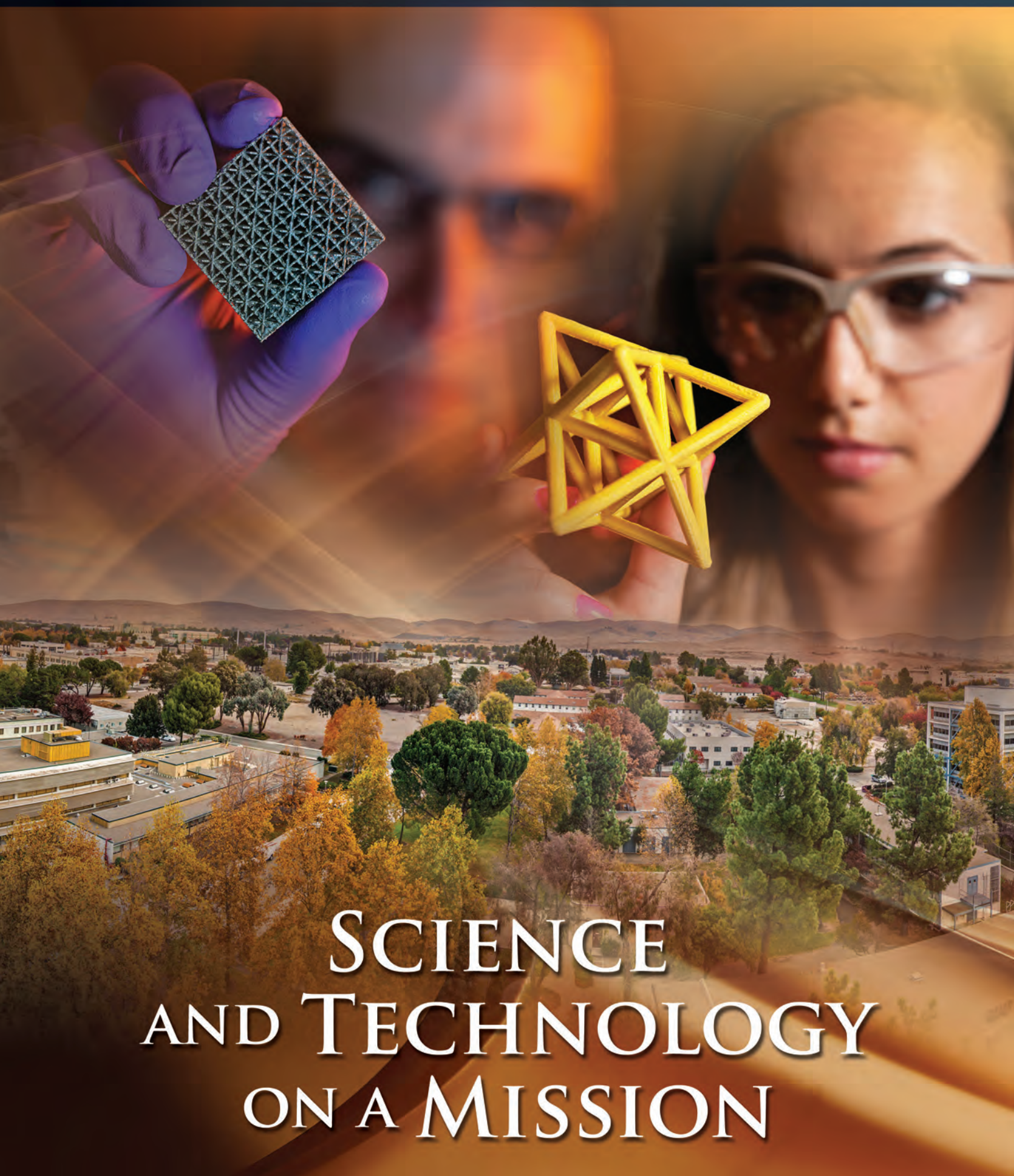


FY 2014 ANNUAL REPORT
LAWRENCE LIVERMORE NATIONAL LABORATORY

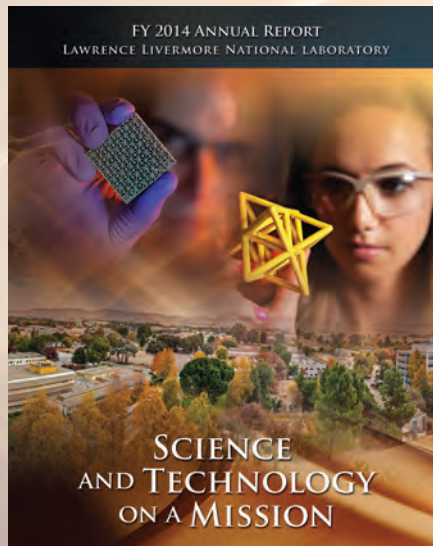


SCIENCE
AND TECHNOLOGY
ON A MISSION

About the Laboratory:

Lawrence Livermore National Laboratory (LLNL) was founded in 1952 to enhance the security of the United States by advancing nuclear weapons science and technology. With a talented and dedicated workforce and world-class research capabilities, the Laboratory continues a tradition of science and technology innovation—anticipating, developing, and delivering solutions for the nation's most challenging problems.

The Laboratory is managed by Lawrence Livermore National Security, LLC (LLNS) for the National Nuclear Security Administration (NNSA), a semi-autonomous agency within the U.S. Department of Energy (DOE). LLNS is a limited liability company managed by Bechtel National, Inc.; the University of California; BWX Technologies, Inc.; and URS Energy & Construction, Inc. Battelle Memorial Institute also participates in LLNS as a teaming subcontractor. Cutting-edge science is enhanced through the expertise of the University of California and its ten campuses and LLNS' affiliation with the Texas A&M University system.



About the Cover:

LLNL's fiscal year (FY) 2014 Annual Report cover features pioneering work by Laboratory researchers in additive manufacturing for NNSA and broader applications. The octet-truss design (yellow) makes possible lightweight structural materials that could prove very valuable to NNSA and industries such as aerospace and automotive. The truss' complex microstructure can only be constructed by three-dimensional printing. A panoramic view of the Laboratory provides the backdrop.



Lawrence Livermore National Laboratory

Managed
and
Operated by



a Limited Liability
Company comprised
of Members



and supported
by Teaming
Subcontractor



© 2014. Lawrence Livermore National Security, LLC. All rights reserved. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.

Disclaimer

This document was prepared as an account of work sponsored by an agency of the United States government. Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy, National Nuclear Security Administration under Contract DE-AC52-07NA27344.

BRET E. KNAPP 1958–2014

Soon after Bret E. Knapp became acting Laboratory director in November 2013, he sent a message to Lab employees expressing his feelings about returning to the place where he started his distinguished career:

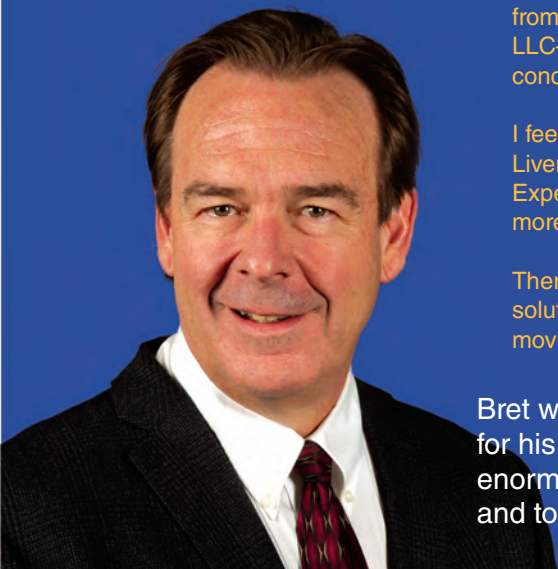
“ It is great to be back here at Livermore. I am honored and humbled to serve as your acting director. Lawrence Livermore has seen enormous change over the last several years, and as testament to its enduring ability, the Laboratory continues to shine as one of the most respected technical institutions in the world. The credit goes to all of you.

Back in 2006, when I left to join Los Alamos National Laboratory—as part of the transition from management under the University of California to Los Alamos National Security, LLC—I had no way of knowing I would return. I am here to help you, to listen to your concerns, to learn from you and, ultimately, to lead us toward continued success.

I feel very much a part of the Laboratory family. As some of you know, I grew up in Livermore and attended school here. My father served as this Lab's first Nuclear Experiment Test Director, and it was at this Lab where I met my wife, who worked here for more than 30 years.

There is no doubt in my mind we will continue to provide amazing science and technology solutions to meet the global challenges that face us all. Together, we will keep the Lab moving forward.”

Bret will be sorely missed. Our Laboratory was honored by his return and thankful for his graceful, steady, and effective leadership. Bret will be remembered for his enormous contributions to our Laboratory, to Los Alamos National Laboratory, and to our nation, which he proudly served.



INSIDE FY 2014

2 SCIENCE AND TECHNOLOGY ON A MISSION

4 NUCLEAR DETERRENCE

6 NATIONAL IGNITION FACILITY

8 GLOBAL SECURITY

10 ENERGY AND ENVIRONMENT

12 SCIENCE AND TECHNOLOGY

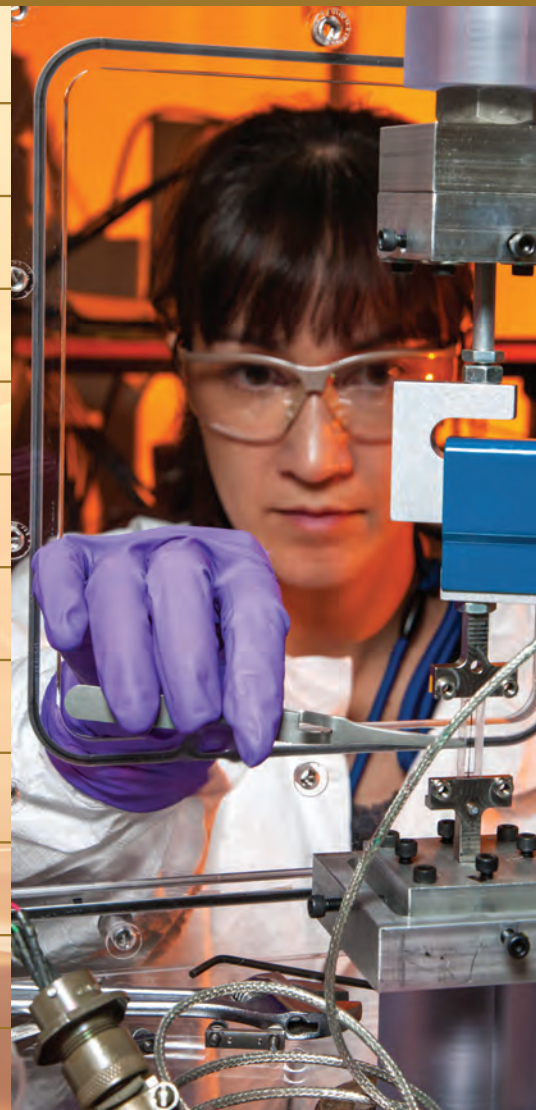
16 SAFETY, SECURITY, AND SUSTAINABILITY

18 MANAGEMENT AND OPERATIONS

20 COMMUNITY CONNECTIONS

22 WORKFORCE RECOGNITION

24 LLNS ORGANIZATION AND ANNUAL COSTS



SCIENCE AND TECHNOLOGY ON A MISSION

At Lawrence Livermore National Laboratory, “Science and Technology on a Mission” delivers solutions for the nation’s most pressing problems. We apply innovative science and technology to help the nation respond to current and emerging security threats.

The many accomplishments featured in this FY 2014 Annual Report demonstrate our mission focus, commitment to scientific and technological excellence, and our tradition of delivering innovations for the nation. Working at the frontier of what is possible and striving for game-changing solutions, we address issues of national and global importance.

Advances in three areas merit special mention. In FY 2014, we achieved major successes in high-performance computing (HPC), the use of the National Ignition Facility (NIF) for

high-energy-density science, and the pursuit of advanced manufacturing methods relevant to national security. These accomplishments are particularly important to our core responsibility—nuclear deterrence—and they have far-reaching implications for all of our mission areas.

Our Laboratory’s defining purpose is sustaining confidence in the nation’s strategic deterrent without nuclear testing. As part of this responsibility, we execute the Stockpile Stewardship Program for the Department of Energy’s (DOE’s) National Nuclear Security Administration (NNSA). The stewardship program represents an unprecedented challenge, requiring rigorous application of the scientific method to extend our understanding of weapons phenomena, assess the condition of weapons, and, when necessary, pursue programs to extend the stockpile life of aging systems.

Assessments depend on using computer simulations to model complex physical processes that occur in detonating nuclear weapons. Sequoia, one of the world’s most powerful supercomputers, is advancing the state of the art in this area. However, greater predictability is needed in weapons physics simulations to extend confidence in the stockpile well into

LLNS Board
of Governors
Chairman
Norman Pattiz
(left) and
Laboratory
Director William
Goldstein.



the future. DOE recently announced that a next-generation supercomputer—powered by millions of cores—will be delivered to Livermore in 2017. This acquisition is part of a concerted DOE effort to sustain U.S. leadership in HPC and meet NNSA mission needs.

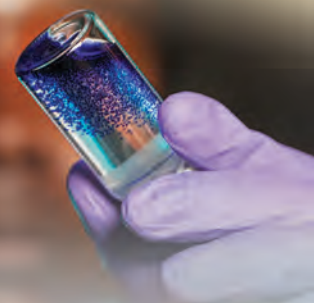
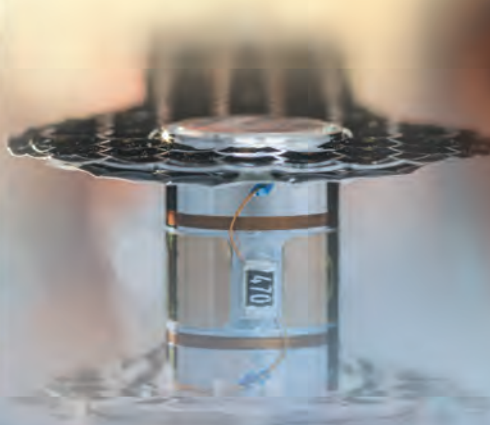
HPC is a defining strength of the Laboratory. Computing and simulation are central to almost everything we do here. FY 2014 accomplishments supported by HPC in nonproliferation, climate change, cybersecurity, drug discovery, and many other areas are also highlighted in our Annual Report.

Of course, the simulation codes used to assess the performance and safety of weapons must be validated. This is the role played by our experimental facilities, and NIF is our flagship capability for exploring the extreme conditions and complex processes that occur in a functioning nuclear weapon. In addition to testing our simulations, NIF develops and sustains the skills of our weapons scientists and serves an expanding user community that is opening up an exciting new field of scientific discovery. Remarkable accomplishments in FY 2014 include demonstrating “self-heating” of a fusion plasma—a key step needed to achieve fusion ignition and burn—and re-creating in the laboratory the conditions that exist inside giant planets.

While the stewardship program has been exceptionally successful in developing and applying new tools to understand our aging stockpile, programs to extend the service life of aging weapons systems have been lengthy, costly endeavors. We can do better. Toward this end, LLNL is pursuing new, paradigm-changing approaches to manufacturing, including three-dimensional printing. Our many FY 2014 successes in this area are attracting broad interest. We have introduced additive manufacturing to production processes used in the nuclear weapons enterprise and created new materials with novel properties that may have wider application. In addition, Livermore has demonstrated the value of applying HPC to advanced manufacturing to help accelerate the cycle from design concept to engineered product. As in most other program areas, much of our manufacturing research involves collaborations. In pursuing our mission, we seek opportunities broadly to expand partnerships with sponsors, other laboratories and research institutions, academia, and U.S. industry.

Our many programmatic accomplishments and continuing attention to safe, secure, sustainable, and effective operations are a credit to LLNL’s outstanding workforce. Remarkable individuals and highly motivated teams are focused on mission delivery and dedicated to national service. As we look to the future, the Laboratory must continue to attract and retain a diverse staff that delivers vision, quality, integrity, and technical excellence.

Lawrence Livermore’s “Science and Technology on a Mission” focuses frontier research on important national objectives. It’s an exciting challenge that we eagerly pursue.



NUCLEAR DETERRENCE

Ensuring the safety, security, reliability, and effectiveness of the enduring stockpile

LLNL's foremost responsibility is to ensure the safety, security, reliability, and effectiveness of the nation's nuclear arsenal. The knowledge gained through experiments, theory, and simulations is applied to assess the condition of stockpile weapons and to develop and certify needed modifications with confidence in the absence of nuclear tests.

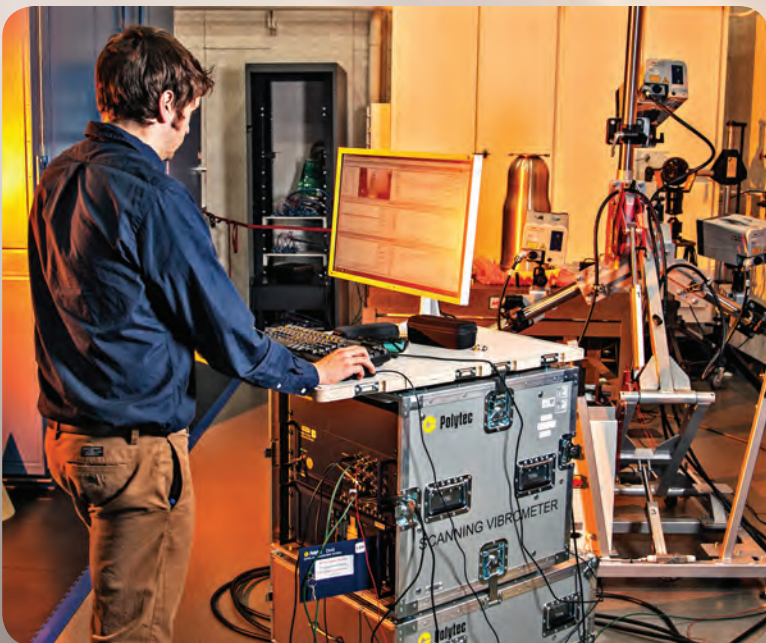
Annual Stockpile Assessment

In FY 2014, LLNL increased rigor and quality in Cycle 19 of the annual stockpile assessment. As part of the overall process, the nuclear design laboratories (Livermore and Los Alamos) jointly conducted a comprehensive peer review of each other's designed weapons. Laboratory scientists continue to improve the baseline weapons-physics simulation codes that support the annual assessments and certification of weapons. This year, Livermore weapons experts also conducted a special peer review for Los Alamos pertaining to a weapons-system significant finding. In addition, Livermore responded promptly and effectively to a number of high-priority special taskings from NNSA headquarters.

Life-Extension Programs

In July 2014, NNSA and the U.S. Air Force formally began a yearlong Phase 6.1 study to prepare conceptual warhead designs for the bomber-delivered Long-Range Standoff

Engineer Eric Ruggiero uses a new laser vibrometer system at Site 300 for structural characterization experiments as part of development activities for the Long-Range Standoff warhead.



(LRSO) missile. LLNL is partnered with Sandia National Laboratories as the design agencies to develop and certify the LRSO warhead. Phase 6.1 activities will further refine designs that employ the W80 nuclear explosive package (NEP), which was selected by the Nuclear Weapons Council based on the results of extensive pre-Phase 6.1 studies. Conceptual designs will include cost-aware assessments of innovative options to improve performance, safety, and security.

The Laboratory closed its efforts on the Phase 6.2 study to extend the life of the W78 Minuteman III warhead following NNSA's decision to postpone work on the W78/88-1 life-extension program (LEP) for five years. As the lead nuclear design laboratory for the effort, LLNL worked closely with Los Alamos on aspects pertaining to the Navy's use of the weapon, and the two laboratories formed a joint design team. The successful collaboration produced a suite of design concepts that enabled completion of NEP down-select in 2014.

Advanced Manufacturing for the NNSA Complex

Livermore researchers are exploring the use of additive manufacturing (AM) to develop next-generation manufacturing processes and materials for the NNSA complex. The goal is to accelerate development-to-production cycles, offer options to decrease plant footprint and reduce waste material, and provide lower-cost parts that have more desirable material properties. The

Technician Manuel Iniguez holds the first additively manufactured part, a match drill fixture, to be qualified for NNSA production at Y-12.



first piece made by AM, a tool called a match drill fixture, has already entered use at the Y-12 plant. The part was designed by Y-12, printed at LLNL, and qualified by Y-12. In other wide-ranging collaborations, LLNL is demonstrating AM techniques for making lightweight structural materials, polymer cushions, and pads for weapons applications. Laboratory researchers are also devising AM methods for printing exotic materials such as high explosives and actinides.

Advances in Supercomputing

The Sequoia supercomputer is a shared resource among the NNSA laboratories for assessing the condition of the stockpile, better understanding aging issues and resolving significant findings in weapons systems, and carrying out LEPs. Experts run large suites of simulations to better quantify uncertainties and also solve large problems with higher-fidelity, more predictive physics models. As an example, LLNL scientists ran a complex high-energy-density hydrodynamics simulation that efficiently used more than 75 percent of the machine's capacity and ran over many days. Sequoia demonstrated the ability to perform sustained large-scale, massively parallel simulations that address important materials-performance issues. NNSA included Sequoia's accomplishment in its 2014 "Getting the Job Done" list.

LLNL is preparing for delivery of a next-generation supercomputer, to be called Sierra, from IBM in 2017. Procurement is part of the DOE-sponsored collaboration between Oak Ridge, Argonne, and Lawrence Livermore national laboratories (CORAL) to accelerate the development of HPC to meet mission needs. As an NNSA Advanced Computing and Simulation program asset, Sierra is expected

to provide about a fivefold improvement in performance over today's top machines.

Stockpile Stewardship Experiments

A wide range of experimental activities in FY 2014 advanced scientific understanding of nuclear weapons and supported the needs to sustain the stockpile and pursue LEPs. Four of the 10 shots that researchers fired at LLNL's Joint Actinide Shock Physics Experimental Research (JASPER) facility, located at the Nevada

National Security Site, were experiments to determine the high-pressure shock compression properties of plutonium to unprecedented accuracy. In addition, 156 experiments were conducted at NIF for the Stockpile Stewardship Program (see p. 6 for details).

LLNL completed all planned work in FY 2014 in support of the national hydrotest program, including technically challenging integrated weapons experiments using hydrodynamic testing facilities at Los Alamos and the Contained Firing Facility (CFF) at LLNL's Site 300.



Advanced Conventional Munitions

The development of advanced conventional munitions exercises critical skills and capabilities needed for stockpile stewardship. In FY 2014, Livermore led the design and execution of a highly successful hypersonic sled test for an LLNL-designed conventional warhead at Holloman Air Force Base (dry-run test shown). Weapons designers and engineers effectively integrated high-fidelity computer simulations into the testing cycle to rapidly accelerate the process from design concept to deployment. Earlier work on the BLU-129/B for the U.S. Air Force earned the Laboratory and partners the prestigious William J. Perry Award in 2014.

For example, an innovative pit-reuse concept, which promises significant cost savings in future LEPs, was successfully tested at CFF in October. Livermore technicians also supported a cold-temperature shot at CFF to provide a performance baseline for a Los Alamos weapons system. In another collaboration, the laboratories achieved a key experimental first in a scaled hydrodynamic test.

The CORAL team is working with IBM, NVIDIA, and Mellanox to deploy systems of about 150 petaflops to advance science and ensure national security. IBM's Sierra supercomputer will be delivered to LLNL in 2017.



Supporting stockpile stewardship through nonignition experiments and pursuit of laser fusion ignition, and operating as a national user facility for high-energy-density science

During FY 2014, a total of 191 shots on target were fired at NIF, including 156 shots for stockpile stewardship: 74 fusion-ignition and 82 high-energy-density (HED) science experiments. Seventeen additional experiments explored fundamental science and supported other national security applications. NIF is serving as a highly productive cornerstone of stockpile stewardship, providing valuable insights into the nature of the universe, and advancing the prospect of laser fusion as a carbon-free energy source.

Record-Setting Neutron Yield

As reported in February 2014 issues of *Physical Review Letters* and *Nature*, experiments at NIF clearly demonstrated “self-heating,” a mechanism needed to achieve ignition and sustained fusion burn. The shot on March 4, 2014, imploded a tiny cryogenically cooled deuterium–tritium capsule and broke the NIF record for number of neutrons produced (9.6×10^{15} neutrons). Alpha particles (helium nuclei) from fusion reactions further heated the plasma in a central hot spot and produced more than half of the total fusion yield (27 kilojoules). The fusion yield was considerably more than the energy imparted to the imploding deuterium–tritium fuel.

These successful shots are part of the “high-foot” campaign. The “high-foot” laser pulse is shaped in a way that reduces hydrodynamic instabilities and breakup of the imploding shell; however, overall compression in the implosion is less. Experimental results are remarkably close to simulations, which is important for understanding and improving performance. Other specialized experiments are designed to better characterize the time-dependent shape of the imploding capsule, optimize the shape and materials used in

In the NIF control room, physicists Dave Farley (left) and Peter Celliers and scientist Curtis Walters monitor the deuterium fill of a capsule during a shock-timing experiment that gathers valuable data for subsequent ignition experiments.



the hohlraum, and study the mix of fuel and capsule material during the implosion. In addition, the first experiments were performed using alternative target capsule materials: high-density-carbon (diamond) and beryllium.

Stockpile Stewardship HED Science Experiments

In FY 2014, campaigns of HED science experiments at NIF explored wide-ranging physical phenomena central to stockpile stewardship. Altogether, 86 HED shots provided valuable data about the properties of materials at extreme conditions, the interaction of matter with intense radiation, and hydrodynamic turbulence and mixing. These issues are critical to understanding nuclear weapons performance and improving the predictability and results of fusion-ignition experiments. As an example, shots using tantalum foils tested an experimental platform to characterize the strength of high-Z (high-atomic-number) materials at high pressures and low temperatures by measuring the growth of hydrodynamic instabilities with x-ray radiography. Experiments at 5 million times Earth’s atmospheric pressure (5 megabars) with high-Z material are planned for FY 2015.

Exploring the Universe at NIF

As reported in the July 17, 2014, issue of *Nature*, scientists for the first time have experimentally re-created the conditions that exist deep inside giant planets. The study focused on carbon, which has an important role in many types of planets within and outside our solar system. Using NIF, a team from the University of California, Berkeley; Princeton University; and LLNL squeezed diamond samples to 50 megabars—comparable to the pressures at the center of Jupiter and Saturn. The laser intensity as a function of time was carefully

A metallic case called a hohlraum holds the fuel capsule for NIF experiments. Researchers are exploring options for hohlraum shape as well as alternative capsule materials to optimize performance in fusion-ignition experiments.



tuned to compress the material without shocking and heating it. Diamond is the least compressible material known; yet, researchers were able to squeeze it to a density greater than lead at ambient conditions.

Also in July, an international team of scientists fielded the first NIF Discovery Science experiment, designed to create and study collisionless shocks. Driven by plasma instabilities and self-generated magnetic fields, such shocks are responsible for the properties of supernova remnant expansion, gamma-ray bursts, and jets from active galactic nuclei. NIF is uniquely able to create at the microscale the proper plasma conditions to generate fully formed collisionless shocks and strong magnetic fields. In the highly successful experiment, laser beams irradiated two foils to create high-velocity counter-streaming plasmas that interacted.

Effective Operations as a User Facility

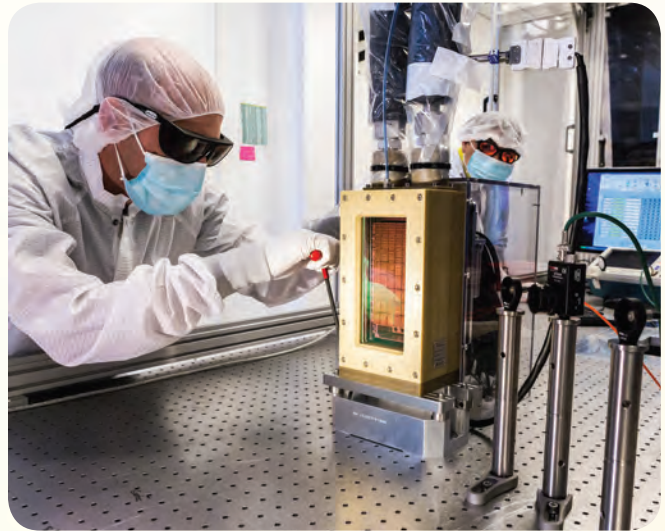
Planning, scheduling, and efficiency changes enhanced productivity and resulted in a continuous increase in the number of experiments NIF conducted in FY 2014. In the fourth quarter, the weekly average was 6.9 laser shots with targets—more than double the 2.8 shots per week achieved in the first quarter. For the fiscal year, the NIF team completed a total of 191 target experiments (those mentioned above plus 18 diagnostics and systems qualification shots) compared to a budget-constrained original planned total of 150.

The implemented improvements greatly benefited from the efforts of a national team of NIF collaborators and sponsors that examined NIF operations in detail. They conducted a congressionally mandated 120-day study to identify ways of increasing the NIF shot rate over three years at constant annual funding and, ultimately, recommended about 80 specific actions. The NIF team adopted a model used successfully at the OMEGA Laser Facility at the University of Rochester and now shoots around the clock for five days, followed by 48 hours of maintenance. Other changes included using “mini-campaigns” designed to minimize facility changes and implementing the award-winning “Formula One” fast-turnaround operations model (see p. 19).

Meeting Broader National Security Needs

The first tests exploring system-generated electromagnetic pulse (SGEMP) were performed on NIF in FY 2014. Conducted in partnership with Sandia National Laboratories and the United Kingdom's Atomic Weapons Establishment, these experiments gathered data to validate simulation

Senior Mechanical Engineer Kurt Boehm performs the initial checkout of a newly designed shroud assembly in the NIF cryogenic target positioner. As part of ongoing efforts to increase operational efficiencies, the new design has reduced shroud installation and alignment time by half.



HAPLS System Components Demonstrated

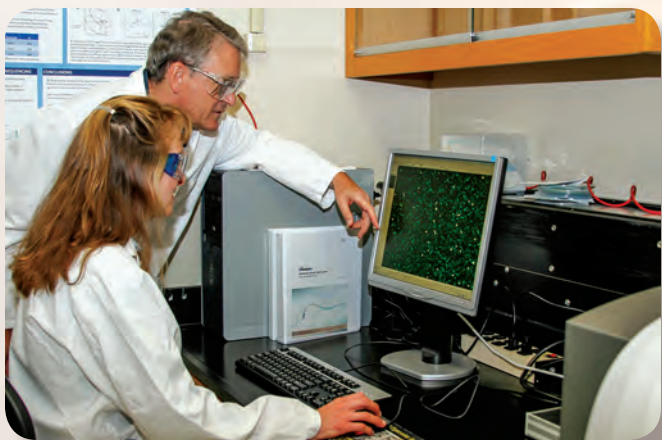
LLNL is developing the High-Repetition-Rate Advanced Petawatt Laser System (HAPLS) for the Extreme Light Infrastructure Beamlines science facility under construction in the Czech Republic. A major advance in laser technology, HAPLS is designed to reach one petawatt (10^{15} watts) of power in ultrashort pulses ten times per second. Key system components are the diode-lasers that deliver 3.2 megawatts of light to pump the HAPLS laser medium. The diodes (shown) consist of four arrays with each array having 45 laser diode tiles.

models for assuring that critical systems are designed to withstand SGEMP effects. In addition, LLNL is developing diode-pumped alkali laser technology for directed-energy applications for the Department of Defense. Significant progress has been made on developing and integrating high-performance laser diodes. Integrated laser experiments reached record power levels in FY 2014.



Reducing the threat from terrorism and weapons of mass destruction and enhancing global stability

LLNL develops innovative advanced technologies to help the government anticipate, identify, and address global security threats. By applying scientific and engineering expertise in chemical, biological, radiological, nuclear, and explosive weapons, our technical experts support threat preparedness, prevention, protections, and response and recovery. Innovations in space situational awareness and cyberdefense help strengthen national security in a highly interconnected world.



Bioinformaticist Shea Gardner and Tom Slezak, LLNL's scientific leader for bioinformatics, look over test results from the Lawrence Livermore Microbial Detection Array.

Rapid Detection of Pathogens in Wounds and Emerging Viruses

Researchers from LLNL and four other institutions demonstrated that the Lawrence Livermore Microbial Detection Array (LLMDA) can detect bacterial pathogens in the wounds of U.S. soldiers. At least one bacterial pathogen was identified in about one-third of wound samples in which no bacteria were otherwise detected using the standard culture method. LLMDA contains 360,000 probes that are capable of detecting within 24 hours any bacteria or virus that has been previously sequenced. The current array version has probes for more than 10,000 species of microorganisms. More effective and timely diagnosis of infections in soldiers' wounds could improve treatment, accelerate rehabilitation, and cut the length of hospital stays.

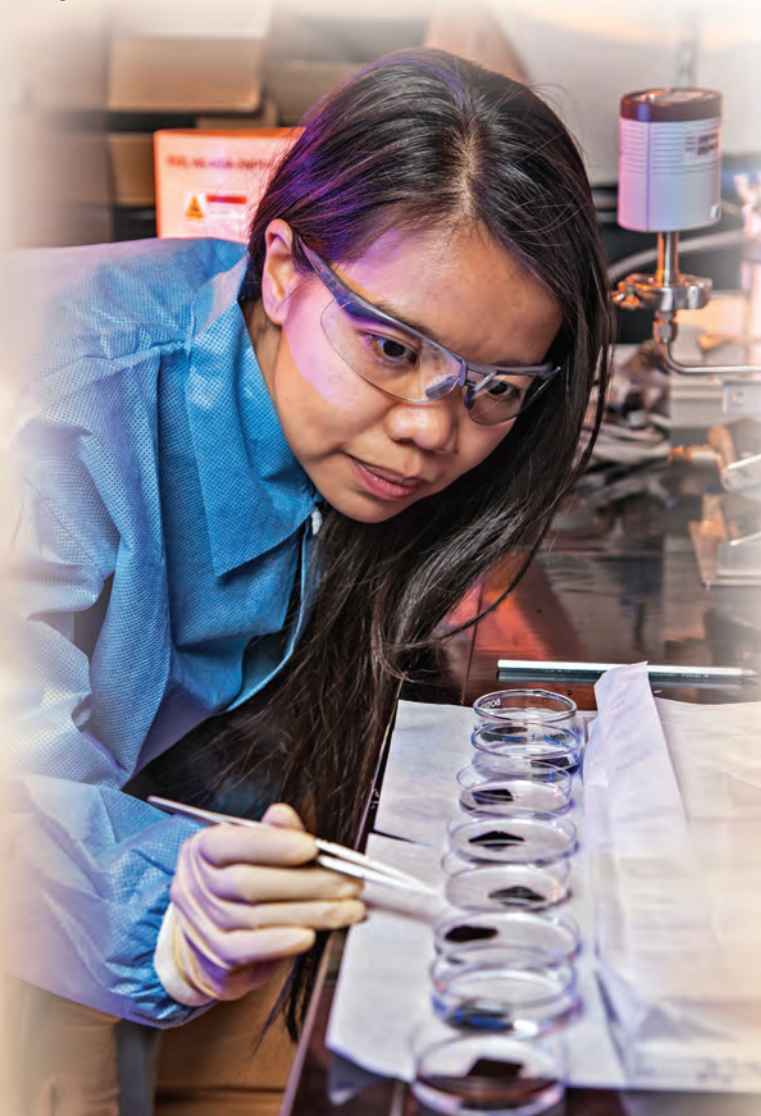
In another study, an international team of researchers from eight nations demonstrated a new rapid method that public health authorities could employ to conduct surveillance for emerging viral diseases. Using LLMDA and a DNA amplification technique developed by researchers from

Denmark, the team correctly identified 29 different emerging viruses in both clinical and nonclinical samples. The disease symptoms for emerging viruses are often similar to those of more common viruses, so it is crucial to quickly identify the correct virus to contain a potential epidemic.

Mapping Networks for Cyberdefense

The Laboratory developed a software-based tool called Network Mapping Systems (NeMS) that provides system owners with a comprehensive view of their computer network environments. Understanding a system's components and structure and their use is the first step in many cyberdefense and mission-assurance operations. The tool builds virtual maps based on observed behavior on the network and offers an interactive analysis platform. Cybersecurity and information technology personnel can then explore the maps

Postdoctoral fellow Ngoc Bui is preparing a set of carbon nanotube membranes for performance testing. The tests show that the breathable fabrics are able to protect soldiers from biological threats like viruses and bacteria.



generated. In one test, NeMS not only identified 100 percent of the network's hosts but also discovered an unknown external connection. NeMS has been successfully deployed for Department of Homeland Security (DHS) at a U.S. government site through remote operation, saving time and travel costs. The software development project was supported by the DHS Transition to Practice Program, and the tool is now available for commercialization.

Smart Suits for Bioprotection

Laboratory scientists are applying nanotechnology to create military-grade clothing for protecting U.S. soldiers from chemical and biological attacks. Protection suits must also be breathable and lightweight. Working with academic partners, the researchers have produced a proof-of-concept patch of material that uses carbon nanotubes in a layer of the suit's fabric. Sweat and air move easily through the nanotubes, but bacteria and viruses are too large in diameter to pass. Chemical agents are smaller, so one option to block them is to include a layer of polymer threads that extends up from the top of the nanotubes. The threads are designed to recognize the presence of agents, swell up, and block them from entering. This nano-based technology has many other possible applications such as temperature-smart blankets and clothing.



In a system test, a truck drives through the Department of Homeland Security's Portal Monitor Test Area at the Nevada National Security Site. (Photo courtesy of NNSA/Nevada Site Office.)

ERNIE On Guard

The Enhanced Radiological Nuclear Inspection and Evaluation (ERNIE) system completed a highly successful preliminary operational assessment at a U.S. port, where it properly classified every radiation alarm during four weeks of testing. The computer application uses machine learning and more than 100,000 scans to analyze data from radiation portal monitors (RPMs). ERNIE reduces false alarms by at



DNATrax on Track

LLNL scientists and engineers developed a safe, odorless, and colorless barcoding material for biodefense applications. The technology has been licensed by DNATrek, which plans to use it as a way to determine where produce was grown, packed, or shipped. The material—called DNATrax—is made of sugar and synthetic DNA particles that are not visible to the naked eye but that can be read by a machine. The encoded information about the produce can then be used to quickly identify the source of contaminated food.

least a factor of 10 while increasing sensitivity to nuclear threats. Unlike current RPM analysis systems, ERNIE uses all the data generated by the RPM—not just gross counts and the ratio of counts in specific energy windows—to provide an assessment of the most likely radioactive source type and location.

Nuclear Test Monitoring Research and Support

Laboratory researchers are at the forefront of developing and exercising methods of monitoring for nuclear tests, and we provide the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) with technical capabilities that support its mission to detect a nuclear test anywhere in the world. LLNL staff members served as task leaders and technical experts at the biannual technical Working Group B meeting held by CTBTO in Vienna, Austria, in February 2014. In addition, in November 2013, LLNL experts co-chaired the On-Site Inspection Workshop 21 held in Yangzhou, China, and a session at the International Noble Gas Experiment Workshop held in Vienna. LLNL experts were also members of the CTBTO Integrated Field Exercise 2014, held in Jordan. The Laboratory is engaged in supportive research to detect noble gases as post-detonation evidence of a clandestine nuclear test, and groundbreaking work on the Regional Seismic Travel Time Model for seismic monitoring earned Stephen Myers an E.O. Lawrence Award in 2014 (see p. 22).

Using science and technology to provide clean, abundant energy, protect the environment, and understand and mitigate climate change

Laboratory researchers apply leading-edge capabilities to develop efficient and environmentally benign energy technologies and to investigate the processes behind climate change.

Enhancing Gas and Oil Extraction

Laboratory researchers have developed GEOS, an advanced supercomputer code that offers hydrofracturing planners a new tool to increase the efficiency, lower the cost, and reduce the environmental impacts of recovering oil and gas from shale. Hydraulic fracturing entails the pumping of a mixture of water, chemicals, and sand into the ground at high pressure. GEOS models the highly complex process of fluid-induced fracture of rock and fracture propagation. It builds on LLNL expertise in geomechanics, seismology, and HPC to predict the behavior of Earth's subsurface with uncertainty estimates. The three-dimensional (3D) code can simulate subsurface fracture networks in a variety of geological settings. GEOS operates at multiple temporal and spatial scales to properly model fracture details while tracking long-term overall behavior. The oil and gas industry has taken note, and several companies are partnering with the Laboratory to use GEOS.

Improved Estimates of Ocean Warming

Using satellite observations and a large suite of climate models, LLNL scientists have found that long-term ocean warming in the upper 700 meters of Southern Hemisphere oceans has likely been underestimated by 24 to 58 percent. These results are important because ocean heat storage accounts for more than 90 percent of the Earth's excess heat that is associated with global warming, and the Southern Hemisphere oceans make up 60 percent of the world's oceans. Change in sea height is a key indicator of climate change. Detailed climate simulation results for the relative increase in sea surface height between the Northern and Southern hemispheres are consistent with highly accurate satellite altimeter measurements. However, these results are inconsistent with measurements of long-term change in heat content in Southern Hemisphere oceans, which are low by comparison. The difference may be attributed to poor sampling prior to 2004, after which a system of 3,600 automated floats were deployed worldwide. This system provides systematic coverage of the Southern Hemisphere oceans for the first time.

Earthquakes and Dam Design Standards

Researchers at LLNL and the U.S. Army Corps of Engineers' Engineer Research Development Center (ERDC) collaborated in a three-year study for DHS to confirm that design standards for dams effectively serve to prevent failure after earthquakes.

The world's most powerful centrifuge subjected a small model dam to 30 times the force of gravity to mimic a 30-foot dam. The tests generated data to validate LLNL's numerical tools and simulations for evaluating dam design standards.

A global flotilla of more than 3,600 robotic profiling floats (named Argo) provides temperature and salinity data on upper layers of the world's oceans. (Photo courtesy of Alicia Navidad/ Commonwealth Scientific and Industrial Organisation.)



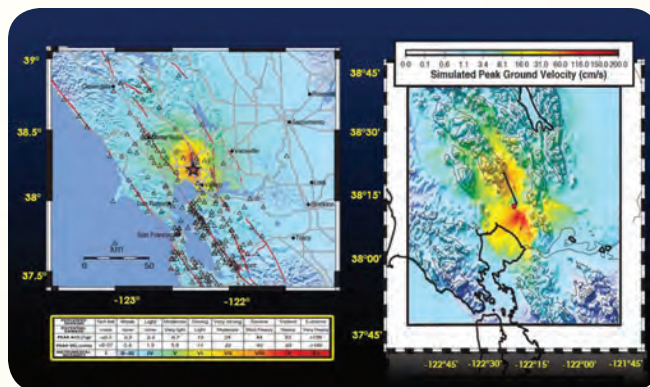
For five decades, soil filters consisting of coarser grain materials have been used to prevent catastrophic failure. The filters aim to prevent rapid erosion of soil particles that could lead to a delayed catastrophic dam failure when a crack forms after a large shock event. Current filter design standards are based exclusively on experimental studies. However, recent advances in time-dependent multiphase fluid and particle modeling allow for a better understanding of soil-grain dynamics. Existing LLNL geophysics models were revised and enhanced to dynamically simulate soil-filter erosion at both the grain scale and at the dam scale. These models were validated to carefully designed erosion, glass bead, and scaled centrifuge experiments conducted at ERDC. In addition to confirming current standards for dam filters, the models can be used to improve filter design and study potential failure mechanisms of full-scale dams due to erosion.

Predicting Wind Power with Greater Accuracy

Laboratory scientists are developing and adapting existing advanced numerical models to help wind farm developers and operators better select wind farm locations and increase operational efficiency. The high-resolution computer simulations must account for complex atmospheric turbulence, which depends on local terrain details, distance above ground, and the effects of nearby turbines in a wind farm. Data gathered from field studies—some conducted at Site 300 and a nearby Altamont Pass wind farm—serve to validate the statistical results from models and associated uncertainty estimates. Among many ongoing collaborations, LLNL and the University of Wyoming experts performed the first-ever simulation of a 50-turbine wind farm that resolves individual spinning turbine blades using realistic turbulent winds.

Efficient Carbon Capture at Power Plants

Working in partnership with researchers from the China Huaneng Group Clean Energy Research Institute, the Laboratory is helping to bring low-cost carbon capture to power plants in the United States. The Huaneng Group had opened a facility that captured carbon dioxide (CO_2) from the 1.320-gigawatt coal-fired Shidongkou number 2 power plant at a cost of \$30 to \$35 per metric ton of CO_2 —much less than the \$100 or greater estimates for first-generation technologies in the U.S. The team gathered data at Shidongkou and Duke Energy's Gibson number 3 plant in Indiana, which LLNL used to build and validate a simulation model for Shidongkou's post-combustion capture process. Researchers simulated a 1-million-ton-per-year post-combustion CO_2 capture system, testing various new capture and solvent technologies for efficient CO_2 capture in retrofits of existing coal plants. A number of design advances over other methods were found, suggesting that a system could be installed at Gibson 3 at a cost of \$61 to \$68 per metric ton.



South Napa Earthquake Simulation

Seismologists used LLNL's supercomputers to simulate the ground motion of the magnitude 6.0 earthquake in south Napa in August 2014. The University of California's Berkeley Seismology Laboratory provided descriptions of the earthquake source and high-resolution LLNL simulations determined how the rupture process affected the region's 3D geological structure. The simulations also examined the impact of surface details on local ground motion. Comparison with observed data serves to improve models, particularly at higher frequencies, making them better tools to study future earthquake scenarios.



A post-combustion CO_2 capture demonstration plant (shown) began operations at the coal-fired Shidongkou number 2 power plant in 2009. It captures 100,000 to 120,000 tonnes of CO_2 per year from a small percent of the plant's flue gas stream.

SCIENCE AND TECHNOLOGY

Expanding the boundaries of scientific knowledge and advancing the technological state of the art to solve problems of national and global importance

Science and technology are central to addressing many of the most difficult problems of the 21st century and to understanding the world around us. Research using LLNL's multidisciplinary scientific expertise and its world-class experimental and computational resources leads to exciting discoveries and innovative solutions.

“Catalyzing” Collaborations and Innovation

Catalyst, a first-of-a-kind HPC cluster, serves as a proving ground for new HPC and “big data” technologies, architectures, and applications. Developed by a partnership of Cray, Intel, and LLNL, the Cray CS300 system is available through the Laboratory's High Performance Computing Innovation Center for collaborative projects with industry and academia. The machine is specially designed for “big data” research, such as business-data analysis and the advanced sequencing of pathogen genomes. Innovations in data-intensive computing are critical to sustaining U.S. leadership in HPC. Catalyst also supports the Advanced Simulation and Computing program by providing insights into the technologies needed for next-generation nuclear weapons physics simulations.

Four R&D 100 Awards

Lawrence Livermore won four awards in this year's R&D 100 competition. LLNL has received 152 awards since the competition began in 1978. The winning technologies are: a Portable Kit for Detecting Explosives and Drugs, a miniaturized thin-layer chromatography kit that can

detect explosives, drugs, and other target substances in samples; the High-Precision Spectrometer for Identifying Trace Elements, a superconducting tunnel junction x-ray spectrometer that can identify unknown substances, such as forensic traces in crime-scene evidence and impurities in computer-chip materials; a Faster, Cheaper System for Polishing Laser Optics, which achieves the precision optics industry's “Holy Grail” of convergence by polishing—quickly, economically, and in a single iteration—optics for imaging systems, lithography, and fusion research; and EXUDE, which allows beams from many small lasers to be combined into a single high-power beam, with applications in advanced defense systems and material processing.

Implantable Technologies for the Brain

The Laboratory is finding wide application for its innovative biocompatible neural interface technologies, which were first used in the artificial retina project. A widely recognized technological breakthrough, the artificial retina partially restores the vision of blind patients. LLNL is developing an implantable neural interface capable of recording and stimulating neurons in the brain to help treat conditions such as post-traumatic stress disorder, traumatic brain injury, and chronic pain. Researchers are also developing the world's first neural device to restore memory loss caused by Alzheimer's disease and other devastating disorders. The goal is an implantable device that stimulates neural tissues to bridge gaps in an injured brain. The implant will connect wirelessly to an external system worn around the ear.



With the system's increased storage capacity and ability to rapidly search massive databases, Catalyst opens opportunities for exploring data-intensive applications such as machine learning and video analytics.

In a unique biomedical research facility at LLNL dedicated to such work, researchers handle a silicon wafer containing micromachined neural devices for implantation inside the human brain.

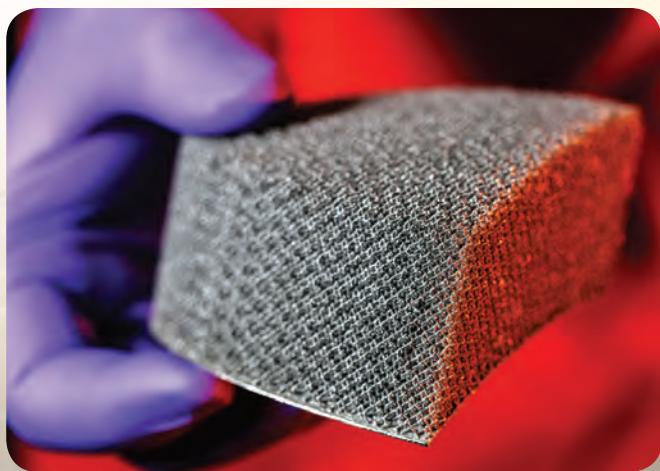


Both of these projects are being performed for the Defense Advanced Research Projects Agency (DARPA) as part of President Barack Obama's Brain Research through Advanced Innovative Neurotechnologies (BRAIN) Initiative. BRAIN aims to find revolutionary new ways to treat and prevent brain disorders. LLNL is also developing an implantable electrode array system to study how neurons in various brain regions work together during decision-making and other complex tasks. More than 1,000 tiny electrodes will be embedded in different areas of the brain to stimulate neural circuitry and record its activity.

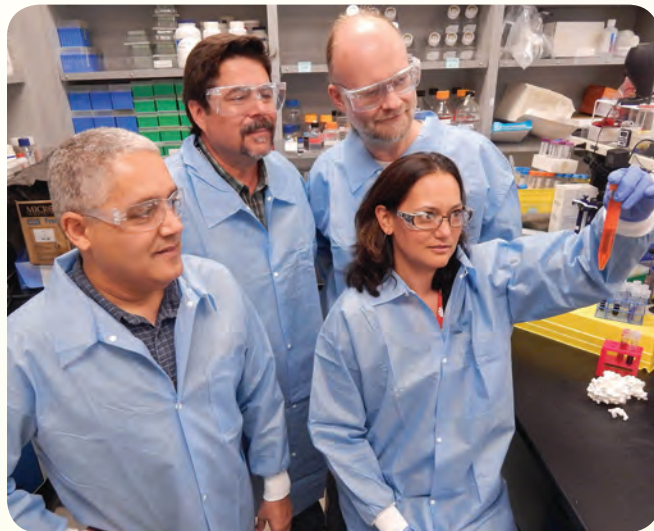
Strong, Ultralight Materials—Printed on Demand

A team from Lawrence Livermore and the Massachusetts Institute of Technology engineered materials that are light yet strong enough to withstand loads 160,000 times their own weight. These materials could profoundly impact industries such as aerospace and automotive. They feature a complex microstructure made possible by 3D printing, an additive manufacturing technique for depositing material and creating the structure one thin layer at a time. The team published its achievement in the journal *Science*. LLNL researchers were also the first to use direct ink writing to create highly flexible, stretchable 3D structures. These lightweight, energy-absorbing materials are "printed" in alternating layers of horizontally and vertically aligned filaments. They could be used to cushion sensitive instrumentation or to protect against extreme temperature changes and vibrations. LLNL's advances in additive manufacturing are benefiting the Stockpile Stewardship Program (see p. 4).

Laboratory researchers also developed a new technique, called light-directed electrophoretic deposition (EPD), to



LLNL researchers are producing titanium alloy lattice structures that are exceptionally lightweight and strong. A combination of modeling and experiments is aiding in their design to ensure their structural integrity.



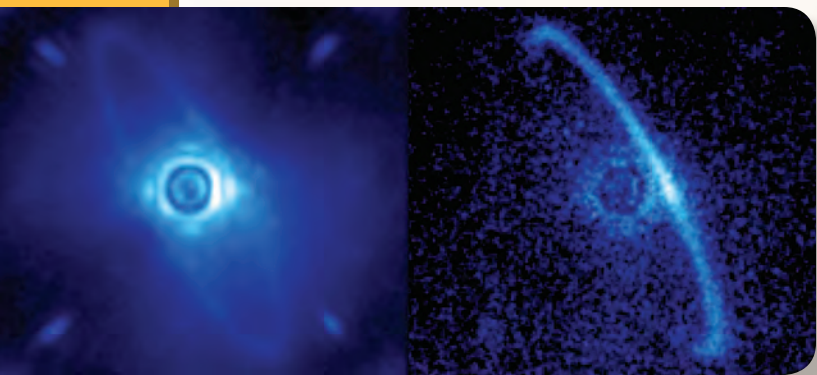
A Patent to Fight Superbugs

LLNL scientists (front row left to right) Matt Coleman, Feliza Bourguet, (back row left to right) Brian Souza, and Patrik D'haeseleer have figured out a way to develop novel antibiotics that effectively kill superbugs. They were recently issued a patent for producing antimicrobial compounds that degrade and destroy antibiotic-resistant bacteria by using the pathogen's own genes against it. Their approach can be used to fight superbugs such as antibiotic-resistant *E. coli*, *Salmonella*, *Campylobacter*, Methicillin-resistant *Staphylococcus aureus* (MRSA), *Bacillus anthracis*, and many others.

dynamically coat a large surface area in fine resolution with multimaterial composites in an arbitrary 3D pattern. For nearly a century, EPD has been used to coat material onto surfaces, for example, applying a primer coat to a new car body on a production assembly line. Until now, this tried-and-true process could only deposit material across the entire surface and not in specific, predetermined locations.

A "Molecular Movie" of Photosynthesis

An international team including LLNL researchers successfully captured, for the first time, the structural changes triggered by light in one of the two large protein complexes responsible for photosynthesis. The team used the world's most powerful x-ray laser—the x-ray free-electron laser at the Linac Coherent Light Source—to perform femtosecond crystallography of the proteins. From the resulting time-resolved data they determined the molecular structures of the complexes in their dark and light-affected states. This work, which shows the tremendous potential of time-resolved femtosecond crystallography for investigating biomolecular processes, was published in the journal *Nature*.



The Gemini Planet Imager viewed the young star HR4796A (left), located 237 light-years from Earth, and captured stunning images (right, polarized light) of a light-reflecting disk of dust orbiting the star.

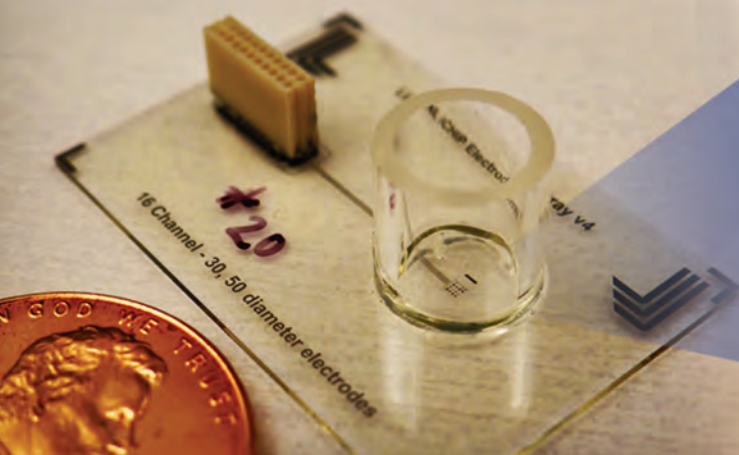
First-Light Images from Gemini

A decade of Livermore-led multi-institutional effort came to fruition when the world's most advanced instrument for directly imaging planets orbiting stars other than our Sun saw first light in FY 2014. The Gemini Planet Imager (GPI)—installed on the Gemini South telescope in Chile—immediately began generating stunning images almost a factor of 10 better than the previous generation of instruments. Key to the imager's performance is an LLNL-designed adaptive optics system. The Laboratory pioneered the field of adaptive optics, which compensate for turbulence in Earth's atmosphere to enhance image clarity far beyond what would otherwise be possible with Earth-bound telescopes.

Advances in “Human-on-a-Chip”

A single chip combining living human cells with tissue engineering and microfluidics technology, the In Vitro Chip-based Human Investigational Platform (iCHIP) aims to reproduce the human body's responses when subjected to drugs, toxins, and other external factors. This “human-on-a-chip” could dramatically speed up development of new pharmaceuticals and countermeasures to biological threats. In FY 2014, the iCHIP team demonstrated human cell response to a surrogate chemical. They also successfully

Inside an iCHIP experimental well, dorsal root ganglia cells are attached to a microelectrode array. Electrodes (black circles) stimulate and record tissue response.

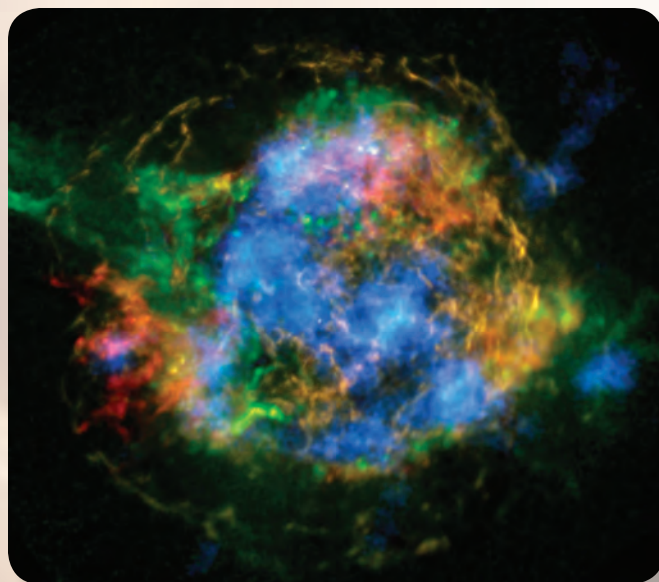


cultured rat neurons on the device for three weeks. These achievements support two key goals needed to make iCHIP-based research a reality: using living human cells as an accurate surrogate for the human body and sustaining those cells for long periods.

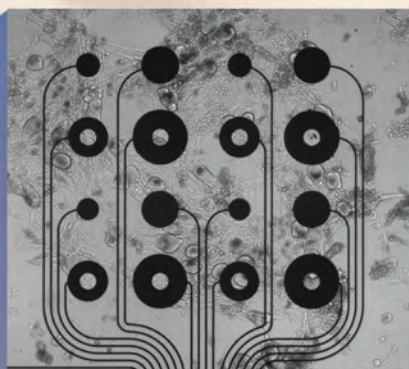
Understanding Supernovae and Solar-System Formation

An international team of astrophysicists using NASA's Nuclear Spectroscopic Telescope Array (NuSTAR)—for which Livermore did important optics design and testing—advanced our understanding of how stars explode in a supernova. NuSTAR mapped emissions from the decay of titanium-44 in the supernova remnant Cassiopeia A. Published in the journal *Nature*, the team's findings confirm that the original star's explosion was not smoothly spherical and suggest extensive convective motions in the star before detonation.

In addition, LLNL researchers and a colleague at Arizona State University examined calcium–aluminum-rich inclusions in meteorites, which are among the first solids to form in our solar system. The inclusions were found to exhibit highly



Shock waves likely rip apart stars in supernova explosions. NuSTAR's titanium-44 data (blue) for Cassiopeia A is combined with previous data for iron (red) and silicon and magnesium (green) to better understand the explosion process.



different isotopic signatures than younger rocks from Earth, Mars, or the Moon. This research suggests that a supernova sprinkled elements into our solar system after the inclusions had formed—indicating that the solar system grew up in “a rough neighborhood.”

Mass-Spectrometry System Accelerates Analyses

Livermore scientists have made a dramatic advance in the method of sample preparation for biological accelerator mass spectrometry (AMS). Biological AMS is a technique in which carbon-14 is used as a tag to study, with extreme precision and sensitivity, complex biological processes, such as cancer, molecular damage, drug and toxin behavior, and nutrition. The new sample-preparation method accommodates liquid samples (rather than graphite) that can be prepared and analyzed in minutes instead of days.

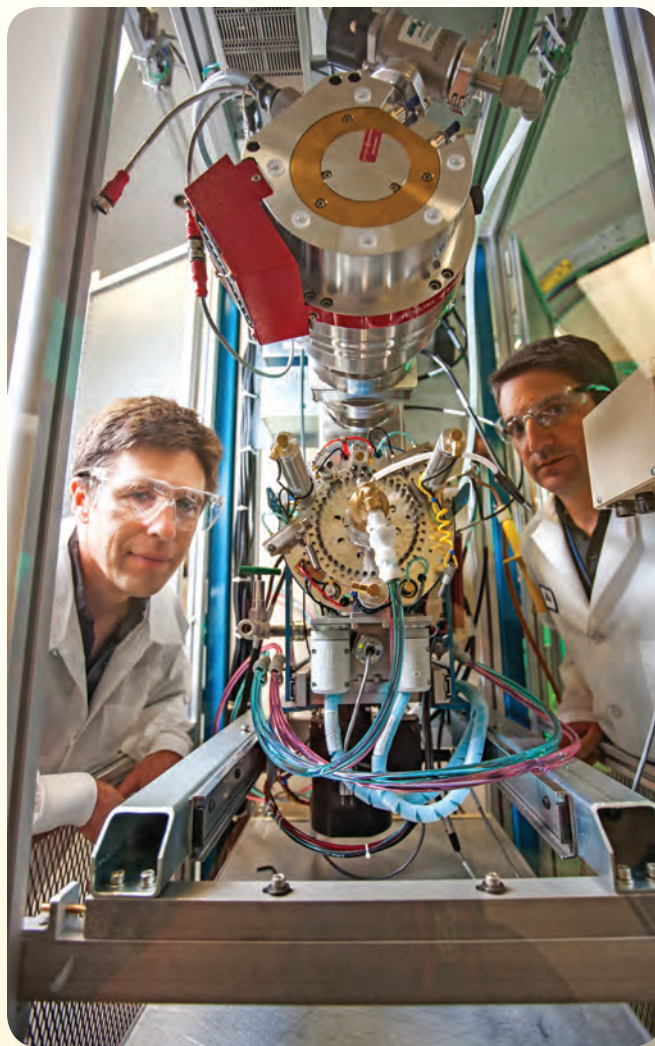
LLNL serves as a National Institutes of Health center for biological AMS. In one project in FY 2014, the capability was used to study unruptured cerebral aneurysms—a potentially life-threatening condition for millions. Researchers found the arterial bulges to be younger than previously thought, suggesting that they alternate between periods of stability and instability. Overturning decades of assumptions about aneurysms, the findings were featured on the cover of the journal *Stroke*.

Predicting Adverse Drug Reactions

LLNL researchers have developed a computational technique to identify proteins that cause medications to have certain adverse drug reactions. Side effects are difficult and expensive to determine as pharmaceuticals are being developed, and if undiscovered prior to a drug's release, pose a major public health risk. The method combines HPC with information from public databases of drug compounds and proteins. The effectiveness of molecular docking was scored for interactions between 906 drug compounds approved by the Food and Drug Administration (FDA) and 409 candidate proteins that have experimentally well-characterized structures. These binding scores were fed into another program and combined with 560 FDA-approved drugs with known side effects. The comparisons allowed researchers to determine which proteins were associated with certain side effects and better predict potential side effects earlier in the drug development process.

Industrial Partnering: Moving Forward

In FY 2014 Livermore obtained 124 new patents, asserted 51 new copyrights, and signed 18 new licenses for LLNL technologies. Licensing income for the year totaled approximately \$10.4 million. Technologies developed by LLNL led to two companies winning the U.S. Small Business Administration's Tibbetts Award for economic impact.



Chemist Ted Ognibene (left) shows the new biological accelerator mass spectrometry (AMS) instrument to biomedical scientist Mike Malfatti. Operations are simplified so that they can be routinely conducted by biomedical scientists, rather than AMS experts.

LLNL's High Performance Computing Innovation Center (HPCIC) is serving as an effective vehicle for outreach to industry and the academic community. The center is located at the Livermore Valley Open Campus, a partnership between LLNL and Sandia National Laboratories—California. HPCIC, as an example, held a technology symposium, hosted by the Silicon Valley Forum, that showcased the Laboratory's capabilities in additive manufacturing. Topics included hardware, enabling materials-science research and development, and application of HPC. In FY 2014, the Laboratory also became a corporate partner of i-GATE, a new startup incubator located in downtown Livermore and launched to connect entrepreneurs to game-changing technologies produced by LLNL and others.

SAFETY, SECURITY, AND SUSTAINABILITY

Achieving safety and security excellence and sustainable environmental stewardship in all Laboratory activities

LLNL is committed to the highest level of performance in the areas of environment, safety, and health (ES&H) and security. Best practices are implemented throughout the Laboratory and management systems provide for continuous improvement. The safety of employees and the public is ensured through prudent risk management coupled with active measures to prevent accidents.

Effective ES&H

The Laboratory's injury and illness statistics continue their long-term downward trend. The FY 2014 total recordable case (TRC) rate of 1.1 continues the prior year's excellent performance and represents a 54 percent decrease since the contract transition in 2008. More significantly, the days away, restricted, or transferred (DART) rate, which is a measure of the severity of injuries, continues to improve to 0.34 and is down by more than 65 percent over the same time period.

Injury and illness reduction goals were met in FY 2014 through continued emphasis on attention to safety and concerted efforts to improve performance in high-risk areas, including facilities and infrastructure operations and protective services. The Laboratory's safety culture was further strengthened by implementing five recommendations and 14 actions proposed by an After-Action Team. The team was formed following the DOE Safety Conscious Work Environment Self-Assessment, which LLNL completed in 2013.

As part of its continual improvement efforts, the Laboratory is undertaking a project to enhance work planning and control (WP&C) in response to incident assessment recommendations and worker feedback. Project plans were created in FY 2014 for taking a strategic approach to address a number of identified issues. Baseline requirements for a new WP&C system have been set, and working groups are developing WP&C processes, controls, and concepts for implementation.

Meeting International Standards

Safe and environmentally responsible work practices at LLNL are supported by high-quality, well-documented management systems. In FY 2014, the Laboratory's Integrated Safety Management System completed triennial recertification of Occupational Health and Safety Assessment Series (OHSAS) 18001 accreditation. In addition, the Laboratory's Environmental Management System, which provides a systematic approach to identifying and reducing the environmental impact of Laboratory activities, holds International Organization for Standardization (ISO) 14001 accreditation. The annual review of this system—as well as a review of LLNL's ISO 9001-accredited Quality Management System—found no nonconformances to ISO standards.

On Track Toward Site Sustainability Goals

LLNL is on track toward meeting ambitious site sustainability goals to reduce fossil-fuel consumption, energy intensity (the energy consumed per square foot of office space), and

LLNL Sustainability Manager Michael Cowen stands next to a reverse osmosis unit. The unit recycles water for a cooling tower needed to operate equipment in the Laboratory's research facilities.



Ergonomics specialist Marissa Mertes provides Jamie Ellison, a deaf interpreting specialist, with a workstation evaluation to prevent musculoskeletal disorders from repetitive motion, which is the most commonly reported injury in an office setting.



emissions while acquiring a greater percentage of consumed energy from renewable sources. For example, LLNL has already achieved its FY 2020 goal for reducing greenhouse-gas emissions by 28 percent, and renewable sources provide 17 percent of LLNL's electrical power, with a goal of 20 percent by 2020. A planned 3-megawatt solar photovoltaic system at the Livermore site will help meet the target.

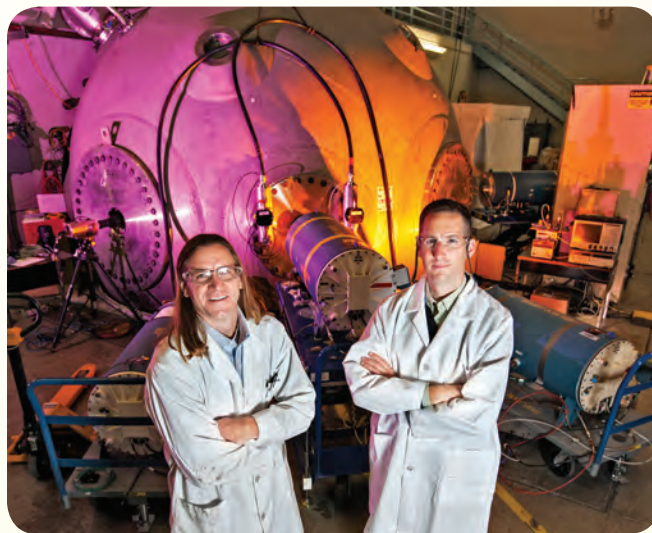
Goals are also in place for reducing water consumption. In view of California's severe drought, water conservation is a critical task, and LLNL cut usage by about 20 percent in FY 2014. Nearly half of the Laboratory's water consumption is directed toward cooling towers for operating high-performance computers and equipment in other research facilities. A reverse-osmosis pilot plant, which began operations in FY 2014, cleans treated groundwater to render it usable in a cooling tower and reduces the need to purchase potable water. Other water consumption is split between domestic use and landscape irrigation. The Laboratory's Sustainable Landscape Concept Plan developed in 2011 and the application of innovative water-conservation technologies enhanced reduction efforts.

Emergency Management Responsiveness

In FY 2014, LLNL's Emergency Programs Organization tested its capabilities with a "severe emergency response" drill and exercise scenarios that entailed multiple, simultaneous events; hazardous material releases; and loss of primary communications systems. Skills in disaster "self-help" were



During their weeklong field study at the Laboratory, students in Georgetown University's Emergency and Disaster Management program learn about special hazardous material operations in a visit to the LLNL/Alameda County Fire Station.



25 Years of Safe Operations at HEAF

LLNL's High Explosives Applications Facility (HEAF) celebrated its 25th anniversary this year. An NNSA Center of Excellence, HEAF is the only facility of its kind. It combines in one location all of the various disciplines and work areas critical to high-explosives research and development. Safe operations are paramount at the firing operations area and at chemistry laboratories for synthesis, formulation, characterization, and testing of energetic materials. HEAF includes seven fully-contained firing vessels, including one (shown) with a firing capacity of up to 10 kilograms net explosive weight.

also exercised. The Laboratory established a Community Emergency Response Team (CERT) program based on the U.S. Federal Emergency Management Agency CERT Program. LLNL CERT, which consists of volunteer employees, supports the emergency response organizations and the LLNL population after a disaster or severe event. The team received eight weeks of special training to enhance its ability to recognize, respond to, and recover from a disaster by offering immediate help to victims as an extension of local first responder services.

Secure Operations

The Laboratory efficiently and effectively maintained secure operations in FY 2014. The Security Organization met all milestones on or ahead of schedule and completed DOE Office of Enterprise Assessments and other inspections with positive outcomes. Security police officers were provided with upgraded training capabilities and received enhanced training on Protective Force authorities. Cybersecurity enhancements included implementing a Risk Management Framework (RMF) for classified systems. RMF moves the security structure from a compliance-based architecture to one that allows LLNL to make risk-based decisions.

MANAGEMENT AND OPERATIONS

Guiding the Laboratory's future course, managing the workforce, improving work processes and business practices, and achieving cost efficiencies

Excellence in management, business, and operations and attention to the needs of the workforce complement LLNL's outstanding performance in science and technology. FY 2014 was a year of management changes and steps to build for future successes.

Bill Goldstein Named Director

On March 27, 2014, William H. Goldstein was named as the Laboratory's director and the president of Lawrence Livermore National Security, LLC (LLNS), which manages the Laboratory for DOE. Goldstein replaces Parney Albright, who

stepped down as director on October 31, 2013. Bret Knapp, who returned to Livermore from a key management position at Los Alamos, adroitly led LLNL as acting director through a critical period following the federal budget sequestration at the beginning of the fiscal year (see p. 1).

Goldstein's "passion for the Lab's mission and people" was cited by Norman J. Pattiz, chairman of the LLNS Board of Governors, as he announced the selection. Goldstein has a distinguished 29-year career at the Laboratory as a physicist and scientific leader with extensive management experience. Prior to being named director, he served as the deputy director for science and technology.



Norman J. Pattiz (center), chairman of Lawrence Livermore National Security, LLC, announced William H. Goldstein (right) as the 12th director of Lawrence Livermore National Laboratory, and thanked Bret Knapp (left) for his service as acting director.

Management Changes and Expanding Partnerships

Director Goldstein and his senior management team, which included many new faces in FY 2014 (see photo below), reaffirmed the Laboratory's role of providing the nation "Science and Technology on a Mission" and developed a strategic vision for moving forward. An important thrust of LLNL senior management is reaching out to expand partnerships with work sponsors, research collaborators, and stakeholders. A top priority is effective communications and strengthened relationships with DOE and NNSA Headquarters, congressional and executive-branch leaders, and the Laboratory's many work sponsors. Within NNSA/DOE, the Laboratory is actively participating—and providing leadership—in many headquarters-contractor initiatives to devise solutions to complex-wide issues.

In addition, LLNL is teaming with other DOE entities in large initiatives such as the CORAL supercomputer partnership (see p. 5) and the DOE Office of Science Accelerated Climate Modeling for Energy (ACME) project. A newly created

At an LLNL senior management retreat in August 2014, the new management team focused on mission priorities, workforce issues, facilities and infrastructure, program development, and other topics.



Strategic Development Office will assist in Laboratory-wide program development activities and in selecting areas of opportunity that engage other federal agency work sponsors. We are also reaching out to academia and U.S. industry through broad initiatives, many of which are tied to the Livermore Valley Open Campus.

Investments in People and Facilities

The Laboratory provides a wide range of employee development, mentoring, and leadership training programs to ensure the continuing quality of its outstanding staff. Senior management's focus is on an active employee recognition program, workforce reviews and succession planning, strong efforts in recruiting, and attention to work-life balance programs and work environment quality serve to meet the needs of a talented, inclusive, and diverse workforce.

Top-notch scientists and engineers are attracted to LLNL by the opportunity to conduct cutting-edge, mission-focused research at world-class facilities. In FY 2014, the Laboratory updated its science and technology investment strategy, which guides institutional investments in exploratory research, capabilities to meet emerging national needs, and LLNL's foundational science and technology base. Investments enabled existing facilities to meet NNSA goals for reliable operation and allowable levels of deferred maintenance. In addition, construction is scheduled to start on three new facilities at LLNL.

Quality Operations

In FY 2014, operations at the Laboratory were effectively and efficiently managed in all principal areas, including business operations and systems; human resources; legal management; facilities and infrastructure; and safety, security, and sustainability (see pp. 16–17). Supply Chain Management and Asset Management at LLNL and the Laboratory's Financial Office earned the highest ratings possible in assessments, and the Financial Office received the

The "Formula One" race car pit-crew model, instituted to improve shot turnaround efficiency at NIF, was developed by one of the nine teams receiving Director's Institutional Operational Excellence Awards in FY 2014.



Strong Research Partnerships

In a visit to LLNL, University of California (UC) President Janet Napolitano pledged to expand university collaboration with the Laboratory. Nearly 25 percent of our published papers are co-authored by UC colleagues, and LLNL is engaged in a growing number of frontier research projects with UC, ranging from President Barack Obama's BRAIN Initiative to work on "big data." Partnerships are also expanding with many other outstanding research institutions, including Texas A&M University, Georgetown University, the New York University Center for Urban Science and Progress, and Rand Corporation. Efforts to partner with industry are exemplified by LLNL's leadership in establishing the California Network for Manufacturing Innovation.

highest rating awarded by the DOE Office of Field Financial Management. In addition to institution-wide continuous improvement efforts, 28 Six Sigma process-improvement projects were completed with projected savings of more than \$12 million, and Management Assurance System performance analysis tools identified ways to improve operational activities in several areas.

LLNS Board of Governors Activities

The LLNS Board of Governors and its committees provided oversight in critical areas related to mission and mission-support activities. The committees delved into their specific areas and members participated in Functional Management Reviews (FMRs) and external review committees (ERCs). In FY 2014, LLNS held seven FMRs in selected topic areas such as performance metrics, work planning and control, the Laboratory's asset management system, the ombuds program, and the Chronic Beryllium Disease Prevention Program. In addition, about a dozen mission/science ERC reviews were conducted. The LLNS Board also approved the Contract Assurance System Annual Assurance Letter, including revisions to ensure that the performance reporting system promotes sustained, responsive engagement with LLNL senior management and the NNSA Livermore Field Office.

Adding value to the community is important to LLNL's continuing success. Each year the Laboratory strives to contribute in meaningful ways, from supporting a wide range of activities in science and engineering outreach to charitable giving and myriad volunteer efforts.

Fun With Science

In FY 2014, more than 8,000 children at the 4th and 5th grade level got up close and personal with science through hands-on experiments. "Fun With Science" presentations by LLNL employees and retirees provide an introduction to various scientific phenomena and help prepare students as they embark on their science education at the middle- and high-school levels.

A Great Day for Science

LLNL's "Science on Saturday" (SOS) lecture series for middle- and high-school students continued to play to sold-out crowds. More than 5,000 people attended a total of 12 lectures held in Livermore, Tracy, and Brentwood. Through SOS, LLNL researchers partnered with local science teachers in discussions focused on demonstrating HPC to simulate the human heart, taking a microscopic look at menacing microbes, understanding fusion in hopes of re-creating the life force of stars, and exploring nature using computers. Presentations are recorded for UC's TV website and YouTube.



Nick Williams, a Laboratory retiree and "Fun with Science" presenter, conducts a science experiment with 5th grade students at LLNL's Discovery Center.

Curriculum that Cuts to the Core

Throughout 2014, Bay Area K–12 science teachers continued to implement new Common Core State Standards in literacy and math. In response, LLNL expanded its professional development academies to help teachers gain the key skills needed to meet this challenge for two high-demand topics. In computer modeling, Laboratory technical staff teamed with local high-school department heads to offer a two-week classroom-ready introduction to basic simulation software. In technical writing, LLNL's practical treatment of ways to meet Common Core requirements filled a pair of two-day workshops attended by Northern Californian science teachers from all grade levels.

Socialization Skills

The Laboratory turned to social media to expand its reach in education. In May, in honor of Livermorium Day, proclaimed by the city of Livermore for LLNL's discovery of element 116, researchers participated in a special "Google chat" with students at Granada High School and Christensen Middle School to discuss exploratory science. The Laboratory also participated in a DOE/NASA Google hangout to promote women in science and engineering, and offered similar online discussions for each of its teacher research academies.

All's Fair

LLNL continues to spread the word on science through various fairs and festivals. In October, the Laboratory participated in the Bay Area Science Festival, which attracted more than 30,000 young scientists and their families to AT&T Park in San Francisco. In addition to daylong presentations

LLNL scientist Harold Rogers' presentation on how to make "elephant toothpaste" was a crowd pleaser at the Bay Area Science Festival, held at AT&T Park in San Francisco.



of “Fun With Science,” attendees were dared to test their scientific know-how or solve the world’s climate and energy issues through interactive computer games. During the festival, Laboratory researchers also participated in the popular “Ask Me Anything” online chats on Reddit, known as the “front page of the Internet.” During this presentation, they were asked more than 600 questions in a two-hour period.

Closer to home, the Laboratory continues to sponsor the annual Alameda County Science and Engineering Fair (ACSEF). Approximately 650 middle- and high-school students and more than 125 teachers from 18 school districts participated in the 2014 fair, with more than 170 awards distributed for 1st, 2nd, and 3rd place, and 60 special awards from national and local government and industry sponsors.

HOME Campaign and Community Gifts

Employees and the Laboratory’s managing contractor, LLNS, raised more than \$3.3 million in the 2013 HOME (Helping Others More Effectively) Campaign, an annual charitable drive that benefits community and nonprofit agencies in the Tri-Valley, San Joaquin Valley, and greater San Francisco Bay Area. Employees pledged a total of \$2.3 million, while LLNS contributed \$1 million in matching funds. The total was \$3.4 million in the 2014 campaign, conducted early FY 2015.

At a ceremony at the LLNS office in Livermore, Laboratory Director Goldstein presented checks totaling \$100,000 to the recipients for the 2014 LLNS Community Gift Program. LLNS received 89 applications totaling more than \$850,000 in requests, a 30 percent dollar increase over the previous year. Thirty-seven applications were selected for awards through a committee review process. The majority of these awards serve children in the Tri-Valley and San Joaquin County, with a focus on science, math education, and cultural arts.



Helping Our Vets

The Laboratory is partnering with Las Positas Community College in Livermore and the Alameda County Workforce Investment Board to establish a 24-month academic program to provide technical education and hands-on training for veterans. The market for qualified technicians can be extremely competitive. With curriculum developed by LLNL, the Engineering Technology Program is designed to help veterans gain skills needed for engineering technician careers and provides a pipeline of candidates to the Laboratory and other Bay Area employers.

Lab employees donated enough items to assemble 122 comfort kits, which will directly benefit foster children through the nonprofit organization “Love ALL Our Kids.” The kits will go into the hands of children in need.



The challenges of LLNL's mission require a workforce of exceptionally talented and dedicated employees. The many awards and honors received by Laboratory personnel are testament to their expertise and the impact of their work.

E. O. Lawrence Awards

Two Lawrence Livermore researchers were recipients of the 2013 E. O. Lawrence Award, which recognizes mid-career U.S. scientists and engineers for exceptional contributions in support of DOE and its mission to advance the national, economic, and energy security of the United States. Stephen C. Myers was recognized for his work developing seismic monitoring technologies to locate nuclear explosions. Former LLNL scientist Siegfried H. Glenzer was recognized for his work on NIF, including full-scale inertial-confinement fusion hohlraum experiments.



Contributing to the Nobel Peace Prize

The Laboratory's Forensic Science Center is one of only two U.S. laboratories accredited to conduct chemical weapons-related testing for the Organisation for the Prohibition of Chemical Weapons, which received the 2013 Nobel Peace Prize for its efforts to eliminate chemical weapons. Livermore performs testing to detect, in samples, traces of the dangerous agents and their precursors—the chemicals used to make the weapons.

PECASE Award

Miguel Morales-Silva was selected by the White House for one of the Presidential Early Career Awards for Scientists and Engineers (PECASE) for 2014. Morales-Silva was recognized for his research on first-principles descriptions of materials at high pressure and temperature using density

functional theory and quantum Monte Carlo techniques. The PECASE awards are the highest honor bestowed by the U.S. government on science and engineering professionals in the early stages of independent research careers.



Office of Science Early Career Awards

Todd Gamblin and Jennifer Pett-Ridge were selected by DOE's Office of Science for Early Career Research Program Awards. Gamblin was selected for his work to accelerate the adaptation of scientific simulation codes to increasingly powerful supercomputers. Pett-Ridge was selected for her study of microbes that drive carbon transformation in tropical soils.

Defense Programs Awards of Excellence

Eleven teams of Laboratory scientists and engineers received an NNSA Defense Programs Award of Excellence in recognition of work performed in 2013 supporting Defense Programs missions. The teams were presented with their awards by NNSA Deputy Administrator for Defense Programs Don Cook.



NIH Director's Early Independence Award

Livermore computational scientist Amanda Randles received a Director's Early Independence Award from the National Institutes of Health (NIH) to help develop tools to predict where in the human body cancer is likely to metastasize. The NIH award provides funding to encourage exceptional young scientists to pursue high-risk, high-reward research in biomedical and behavioral science.



The William J. Perry Award

The team that developed the BLU-129/B low-collateral-damage weapon, which includes contributors from LLNL, received the 18th annual William J. Perry Award in recognition of “the immediate and long-term impact the BLU-129/B has had and will have on combat operations.” The award “also honors the impressive public and private sector partnership that led to this technological advance.”



Air Force Awards for Meritorious Civilian Service

Scott Couture and Steven DeTeresa received U.S. Air Force Awards for Meritorious Civilian Service. Couture was recognized for his work as the Air Force Under Secretary’s principal adviser for nuclear matters. DeTeresa helped the Air Force forge agreements with the U.S. Navy and the United Kingdom’s military establishment.



Young Achievers Award from IEEE

Abhinav Bhatele received the 2014 Young Achievers Award from the Technical Committee on Scalable Computing of the Institute of Electrical and Electronics Engineers. The award acknowledges early-career individuals who have made outstanding, potentially long-lasting contributions in the field of scalable computing. Bhatele’s work focuses on optimizing communications on different supercomputers—often a major bottleneck to scalability.

Society Fellows

Seven Laboratory researchers were made fellows of professional societies. Ken Moody became a fellow of the American Association for the Advancement of Science. Charles Cerjan, Marilyn Schneider, Eric Schwegler, and Ian Thompson were named fellows of the American Physical Society. Regina Soufli was elected a fellow of the Optical Society. Stephen Payne was elected as a fellow of SPIE.

DNDO Award for Exceptional Performance

The Transformational and Applied Research Directorate of the Department of Homeland Security’s Domestic Nuclear Detection Office (DNDO) recognized Natalia Zaitseva and the Laboratory as a whole with the DNDO Award for Exceptional Performance, in recognition of “exceptional support to the mission of DNDO.”

Leadership Award from Fusion Power Associates

John Edwards was named winner of the 2014 Leadership Award from Fusion Power Associates. Edwards was cited for his many scientific contributions and managerial leadership in research efforts on inertial confinement fusion and high-energy-density plasma physics.

Chair of ANS Fusion Energy Division

Susana Reyes was elected chair of the American Nuclear Society’s (ANS’s) Fusion Energy Division. Reyes, who has a long history of service with ANS, works in neutronics and materials-damage simulations in support of high-energy accelerators and NIF, among many other areas.



List of “World’s Most Influential Scientific Minds”

Lawrence Livermore scientists Charles Westbrook and William Pitz were named to the Thomson Reuters list of “The World’s Most Influential Scientific Minds.” Their work on combustion modeling has been incorporated into simulations used by the auto industry and others to optimize engine design and reduce emissions.

OSA Senior Member

Livermore’s Zhi Liao was named a senior member of the Optical Society of America (OSA). Liao was recognized for his contributions to optics research and for his service to the optics community. He has contributed to many of LLNL’s successful laser projects, including the Mercury Laser and NIF.



DTRA Nuclear Forensics Award

The Defense Threat Reduction Agency (DTRA) named Roger White “top contributor” for the third quarter of FY 2013 for leading a multiple-organization team that developed and executed a simulated terrorist-related nuclear event.

LLNS ORGANIZATION AND ANNUAL COSTS

EXECUTIVE COMMITTEE

Norman Pattiz

Chairman; Regent, University of California; Founder, Westwood One, Inc.; Founder and Chief Executive Officer, Courtside Entertainment Group; Chief Executive Officer, PodcastOne and PodCastOne Sales

Craig Albert

Vice Chairman; President, Bechtel Nuclear, Security & Environmental, Inc.

Kimberly Budil

Vice President for Laboratory Management, University of California; Chair of the Nominations and Compensation Committee

John Howanitz

General Manager/Senior Vice President, Bechtel Nuclear, Security & Environmental, Inc.

Robert Powell

Distinguished Professor of Chemical Engineering and Materials Science and of Food Science and Technology at the University of California, Davis; Chair of the Science and Technology Committee

Bob McQuinn

President and Project Manager of Nuclear Waste Partnership, LLC

INDEPENDENT GOVERNORS

Kevin Chilton

General (Retired), U.S. Air Force

Donald Kintzer

Partner (Retired), PricewaterhouseCoopers; Chair of the Ethics and Audit Committee

Steve Koonin

Director of New York University's Center for Urban Science and Progress; Chair of the Mission Committee

Richard Mies

Admiral (Retired), U.S. Navy; Former Commander in Chief, U.S. Strategic Command

The Honorable Ellen Tauscher

Strategic Advisor for Baker, Donelson, Bearman, Caldwell & Berkowitz, PC; Former Member of the U.S. House of Representatives, California 10th Congressional District; Former Under Secretary of State for Arms Control and International Security; Former Special Envoy for Strategic Stability and Missile Defense

ADVISORY MEMBERS

Michael Anastasio

Laboratory Director (Emeritus), Los Alamos and Lawrence Livermore national laboratories

Robert DeGrasse

Vice President and Manager Government Affairs, Bechtel National, Inc.; Chair of the Business, Operations, and Security Committee

Bruce Varner

Chairman, The Regents of the University of California; Partner, Varner & Brandt, LLP

Craig Weaver

Senior Advisor, Bechtel Nuclear, Security & Environmental, Inc.

BATTELLE GOVERNOR

Jeffrey Wadsworth

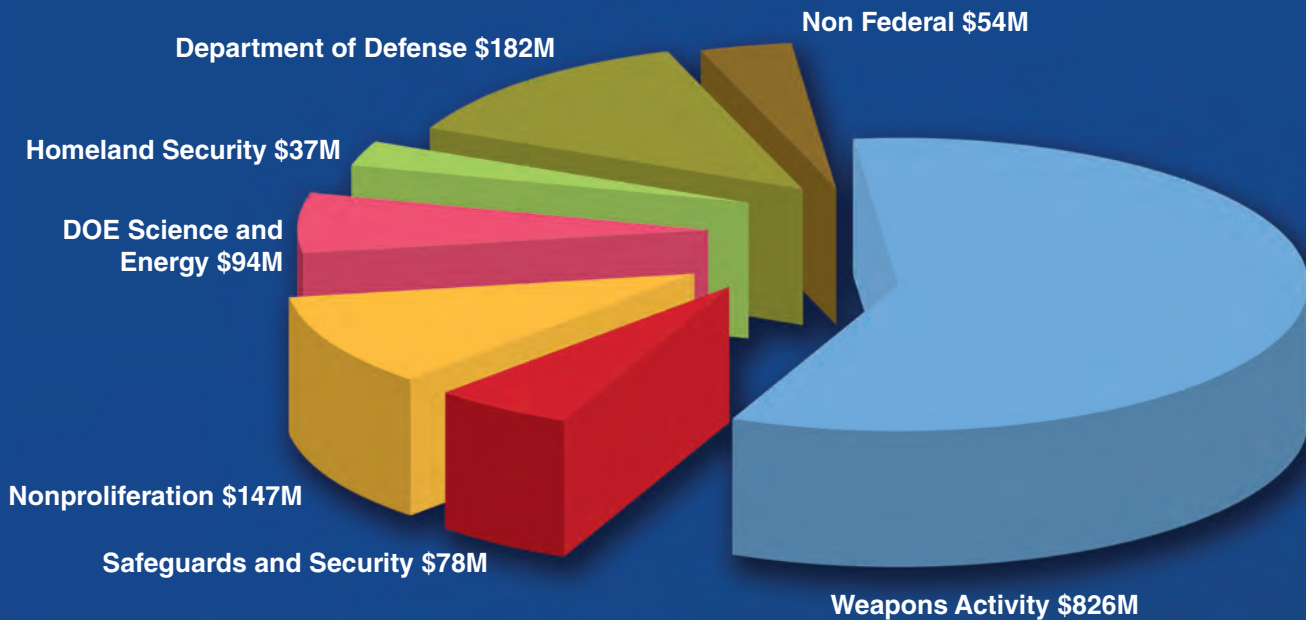
President and Chief Executive Officer, Battelle Memorial Institute

LLNS Board of Governors

Chairman Norman Pattiz (left) and Vice Chairman Craig Albert (right) join Laboratory Director William Goldstein at a joint meeting of the LLNS and Los Alamos National Security, LLC (LANS), boards. The two boards work to better integrate activities and make both laboratories and the NNSA enterprise more effective and efficient.



LLNL FY 2014 Actual Costs: \$1.42 billion



Lawrence Livermore National Security



LLNS is a limited liability company managed by members Bechtel National, Inc.; the University of California; BWX Technologies, Inc.; and URS Energy & Construction, Inc. Battelle Memorial Institute also participates in LLNS as a teaming subcontractor. Cutting-edge science is enhanced through the expertise of the University of California and its ten campuses and LLNS' affiliation with the Texas A&M University system.

January 2015



Managed by Lawrence Livermore National Security, LLC
for the National Nuclear Security Administration of the U.S. Department of Energy